Bubbles and Acoustic Communications Experiment (SPACE07): Acoustical and Physical Characteristics of Diffuse Bubble Plumes

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LONG-TERM GOALS

The scientific rationale for SPACE07 is that even though reliable underwater acoustic communication is central to the Navy's vision and Concept of Operations (CONOPS) for the future, and while significant progress in communications system development has been made in the last 15 years, current techniques fall far short of what is needed in terms of the data rates, the range of environments and operating conditions, and levels of covertness at which reliable communication links can be established. For example, communications in very dynamic environments (e.g., surface scattered environments in rough weather, communications at depth and speed for submarines) or at low SNRs as required for covert communications are areas where progress is still needed. To bridge the gap between current capabilities and future requirements, SPACE07 brings together a team of 10 investigators with world leading expertise in physical oceanography, underwater acoustics, signal processing, information theory and coding, practical modem development, Navy CONOPS and assets, and in the use of autonomous and distributed systems.

The main goal of this project is to investigate the acoustical and physical characteristics of upper ocean bubble plumes from generation to dissolution, especially as they affect the acoustical environment. In-situ and remote acoustical measurements of bubbles, turbulence, surface waves and whitecaps will be combined with ACOMMS experiments run separately by Jim Preisig (WHOI) and Grant Deane's (Scripps) α-plume investigation, so as to permit direct integration of modeling and analysis. This particular project is a collaborative effort between the Institute of Ocean Sciences (Vagle) and University of Rhode Island (David M. Farmer).

OBJECTIVES

The project objectives are to answer the following questions;

(1) how do we use forward scattered 100 and 120 kHz acoustic signals to infer the contribution of turbulence and bubbles to propagation fluctuations? Conversely, how do we exploit the propagation measurements to separate out the natural variability due to turbulence and bubbles from ACOMMS signals of interest? Given the contribution of turbulence and bubbles, how do we characterize the resulting variability so as to allow the optimization of acoustic communications algorithms?

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14. ABSTRACT
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(2) How does surface turbulence (including Langmuir circulation) and bottom boundary layer turbulence influence the distribution of bubbles in the water column, with corresponding effects on propagation?

(3) How does the bubble size distribution depend on wave breaking, turbulence, Langmuir advection and bottom boundary layer turbulence?

(4) Can we use ambient noise as a surrogate for inferring acoustic characteristics of the upper ocean boundary layer? Is the acoustic intensity and spectrum of the noise source related to whitecap speed, dimensions and other properties?

APPROACH

The following measurements will be acquired in October and November 2007:

To study volume acoustic fluctuations and turbulence we will use simultaneous forward propagation and backscatter measurements at 100 kHz along a 40m path (Figures 1 and 2). A 120 kHz 8-transducer scintillation system will also be deployed on two tripods along a 40m path orthogonal to the 100 kHz system path and will be used to investigate flow characteristics and the role of temperature versus velocity fluctuations in modulating the acoustical signals. Reciprocal transmissions will allow separation of scalar and vector components. The two 100kHz sidescan sonars can be aimed towards each other for reciprocal transmissions or rotated horizontally to allow for bubble cloud imaging and Doppler analysis for measurements of the directional wave field. These acoustic wave measurements will be augmented by an array (5 units) of capacitative wave gauges mounted on the tower. Two vertical 50kHz sonars located at each of the 100kHz tripods will be augmented by a separate multi-frequency backscatter system deployed by Andone Lavery (WHOI) in the center of the array, to yield profiles of the bubble clouds and local measurement of the wave spectrum (Thorpe et al., 2003). A thermistor string will monitor sound speed profiles (supplemented with T-S relationship from a recording Seabird 19plus CTD). These observations will be supported by an upward-looking 300 kHz ADCP to measure the overall velocity profile, Grant Deane's (SIO) 3-D ADV at intermediate depth to measure small-scale structure, and Lavery's turbulence and *in situ* salinity measurements of the WHOI tower to measure background turbulence and density structure. The oxygen and nitrogen content (required for modeling of bubble plume evolution) will be monitored using a combination of an oxygen sensor and a gas tension device attached to one of the sonar tripods (Farmer et al., 1993; McNeil et al., 1995). We will also use our upward looking echo-sounders together with a wave following float tethered to a horizontal mooring attached to the tower (Figure 1), measuring *in situ* air-fractions and bubble size distributions (Farmer et al.,1998,2005; Vagle & Farmer, 1998) and Deane's *in situ* bubble size sensors and video imagery to study the air entrainment and bubble size generation associated with photographically observed whitecaps. These will be interpreted in terms of whitecap intensity, size and velocity. The echo-sounders will acquire the diffuse, resonant bubble measurements which will be interpreted in terms of vertical representative bubble spectra, measured dissolved gas concentration, and vertical velocity measurements acquired with Doppler sonar from the sea floor.

Ambient sound measurements will be acquired with two broadband (40-25,000 Hz) hydrophones deployed on the tripods containing the 100 kHz sidescan sonars.

These measurements will be supported by periodic ship-based observations of turbulence profiles acquired with a 3-component coherent 2MHz profiling sonar.

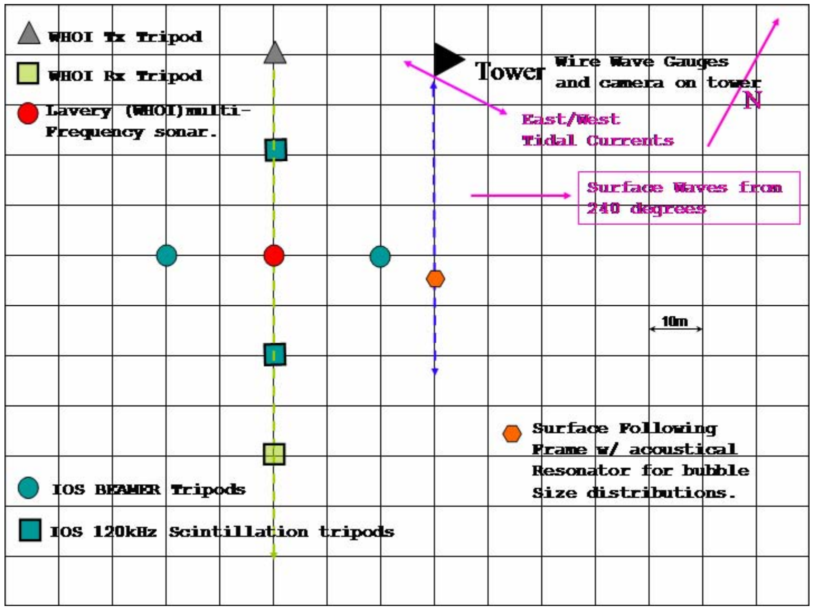

Figure 1. Schematic diagram showing the planned location of the IOS instrumentation tripods and surface following float during the upcoming SPACE07 experiment near the tower at Martha's Vineyard Coastal Observatory (MVCO). Also shown for reference are the multi-frequency system to be deployed at the center of the array by Adone Lavory (WHOI) and two of the ACOMMS tripod to be deployed by Jim Preisig (WHOI).

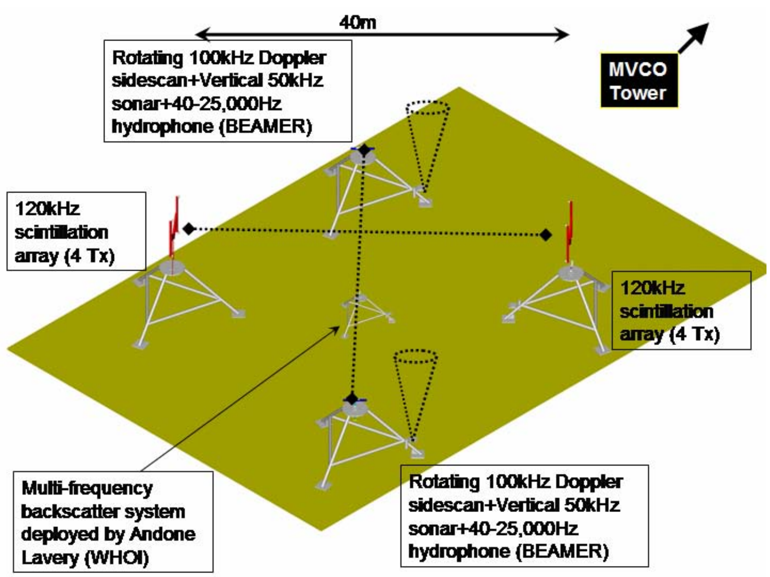

Figure 2. Three dimensional diagram showing the location of the two BEAMER tripods and the two 120kHz scintillation tripods as they will be deployed on the seafloor at MVCO. Also shown is the multi-frequency sonar system to be deployed by Adone Lavory (WHOI).

WORK COMPLETED

All effort so far has gone into preparing the instrumentation for deployment at MVCO in the middle of October. Hardware for two new tripods to carry the scintillation arrays have been shipped to URI and work has started on upgrading the URI BEAMER system for the upcoming SPACE07 measurements. The scintillation array mounting frames have been modified to allow for several array sizes ranging from 1m to 1.5m transducer spacings. The wave following frame with an acoustical resonator for bubble size distribution measurements, a conductivity sensor for high air-fractions, and 2 conductivity and temperature sensors have also been shipped to the east coast. The plan is to assemble to complete system during the week of October 9th at WHOI.

RELATED PROJECTS

This project is an integral part of the ACOMMS MURI project lead by Jim Preisig from WHOI. The surface following float and associated acoustical resonator will also be used in upcoming RadyO field experiments (N000140610379 & N000140710754).

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